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ABSTRACT

A model for educational research and development is presented which, like an agricultural experiment station, would exist to interpret research findings, translating them into usable form. Allocations of funds would be made so that the bulk of the funds would go to the actual utilization levels. A plan for using such educational stations is proposed using television as a means of raising learning capacity by teaching printed language skills to young children. Researchers would focus on systematically deciding what words to present and what sequence to use. Animated cartoons would be broadcast in which children would see picture stories with words incorporated. Such a program would allow translation of research findings to a user level and would capitalize on the advantages of television as a learning mechanism. Very young children would be exposed to the printed word and might well be expected to assimilate reading as easily as they do speaking. Examples of cartoons, a flow chart for developing a reading technology, and references are included. (MS)

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MANAGEMENT PLAN FOR A NATIONAL EFFORT IN READING

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Abstract. This paper presents a plan to raise learning capacity by teaching printed language skills to young children. They will be taught by a daily broadcast of animated cartoons in which words for the child to read expand on screen just as the cartoon character pronounces them. The first step in the plan is to collect a systematic set of tables that calibrates each language unit used in the program. Then these tables will be used to design a progression of experiments that converges upon the optimum list of language units for the year's program--the particular list from which the child can induce the concepts of printed language most efficiently. Next, critical sections of the optimum list will be developed into animated cartoons and polished to a high state of teaching efficiency. These lessons will serve as models from which the entertainment industry will develop the daily broadcast.

A more general purpose of the paper is to present a model for educational R & D patterned after the agricultural experiment station. In the 1830's, shortly after Boussingault initiated agricultural field studies, several of these institutions began experiments that used the methods of chemistry and biology to derive products and systematic tables useful to scientific agriculture. The products and tables were the major impetus for the steady increase in farm production that occurred thereafter. This paper will attempt to show that analogous experiments can initiate equal advances in education.

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RE003 308

MANAGEMENT PLAN FOR A NATIONAL EFFORT IN READING

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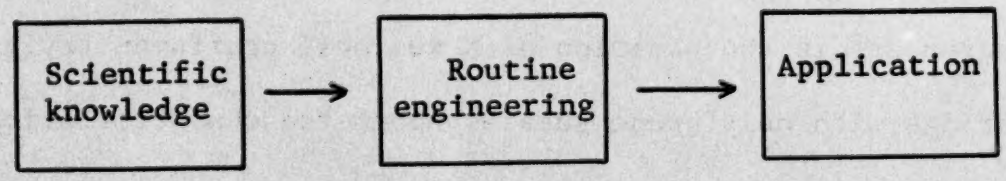
This paper presents a management plan for raising the learning capacity of the American child. Such a national commitment is practical for the 1970's; many studies--ranging from anecdotal case histories to laboratory experiments--show the possibility of increasing learning capacity by training the organism in infancy.

There are reasons for expecting the initial thrust in reaching this goal to come from teaching reading--more generally, from teaching the printed language skills. A recent monograph, "Collecting a Data Base for a Reading Technology" (Coleman, in press), outlined an R & D system for teaching these skills. The monograph was actually a small part of a management plan for a national effort in reading. The present paper will add further details to the plan. The research logic of the plan for reading can serve as the logic for a still more general effort in educational R & D, in brief, establishing a series of educational experiment stations. This rationale can be presented by quoting from the earlier monograph.

> "Although enterprises such as industry, medicine, and agriculture have assembled vast systems for applying the findings of basic science, education has been less efficient in such application (see a review of educational R & D by Chase, in press).



The thesis of this paper is that the inefficiency is occurring because the relation between education (or specifically, elementary reading) and

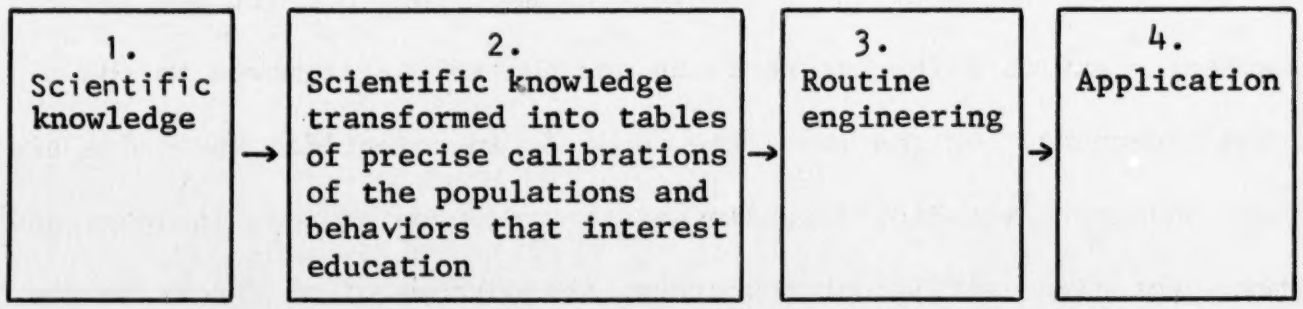
its underlying sciences requires that the scientific knowledge be transformed before any great amount of educational engineering will be possible.

The essence of engineering involves manipulating numbers (or measures) in order to predict what will happen when analogous manipulations are performed upon things. But the sciences most relevant to reading are organized in terms of hypothetical constructs, not measures. In psychology, for example, knowledge about the transfer effect of language habits is organized under such constructs as meaningfulness (m), unit-sequence effects, functional fixedness, etc. To be of use to a reading engineer, this knowledge must be transformed into tables of precise measures that he can manipulate to predict the behavior of a child in a classroom. For instance, he needs to know the transfer effect of a specific English spelling rule when a child sounds out a given irregular word.

An engineer can transform knowledge from the physical sciences into useful tables with straightforward mathematical operations, but the experiments that generated knowledge of interest to reading were usually performed upon learner populations such as college sophomores and upon language populations such as nonsense syllables. There are no mathematical formulas for transforming such knowledge. There are no tables that calibrate the words, letters, phonemes, spelling rules, phonic rules, and other units which compose elementary reading programs. The publishers and writers who try to put the right materials together into an elementary program are in the position of a medieval craftsman trying to put together a bridge with only crude guesses about the characteristics of his materials.

To provide tables that calibrate the language units that compose reading programs, experiments must be replicated upon populations of

direct interest to reading--upon six-year-olds memorizing letter-sound associations, upon children learning to read common words from flashcards, upon children learning to print, etc. In short, another box must be inserted in the flow chart."



The chart could now serve to illustrate an R & D effort in agriculture. As a matter of fact, Rothkopf[1] has commented that the current state of affairs in education resembles that of agriculture in the 1830's. Up to that time, discoveries in chemistry and biology had exerted little effect upon farm production. The spectacular increases in production came as a result of systematic studies as straightforward as ones that measured the effects of particular chemicals upon particular crops in particular soils. The point is that scientific agriculture, especially the agricultural experiment station, may offer more instructive models for education than sciences such as physics or chemistry.

The earlier monograph (Coleman, in press) was concerned with the tables that would be generated by an Educational Experiment Station in Reading. The monograph reported four sets of experiments and outlined the narrowband studies that would have to follow to provide a systematic set of tables for a reading technology. In the present management plan, the entire flowchart for developing a reading technology will be outlined.

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[1]Personal communication

It is worthwhile to pause and study Figure 1 in some detail since it summarizes the overall plan. Note that blocks to the left are prerequisite to those on the right. Note that the upper rows are logically prior to the lower ones. The heaviness of a line represents the dependability of available methods; the breaks in a line represent the percentage of knowledge not yet available.

Management planning gains in precision and control as it moves to the right of the flowchart. On the left, the advances in scientific knowledge are intermittent and unpredictable, depending as they do upon genius, insight, and serendipity. But given sufficient resources, the outcome of an effort in the other blocks becomes progressively more predictable as one proceeds to the right.

On the other hand, management planning loses somewhat in distinctness and administrative control as one proceeds from top to bottom rows. The flowchart has been stratified into three rows that correspond to recoding skills, sentence comprehension skills, and higher-order comprehension skills. Three rows are necessary because there are large differences in the amount and dependability of the scientific knowledge that originates the different rows, and thus each row requires different research strategies, different management techniques, and the allocation of resources to different segments of the research community.

The top row represents recoding skills, the recoding of printed language into spoken language. It concerns the learning of the first 100 to 300 words. To reach the goal in the top row, three blocks must be filled in beginning with Block 2, the collection of tables that measure the effects of language characteristics upon recoding skills. The heaviness of the lines in the top row shows that most of the necessary methods have already been developed. Linguistics and psychology provide precise descriptions of the language characteristics that affect the learning of recoding skills, and the psychology of paired-associate

MANAGEMENT PLAN FOR A NATIONAL EFFORT IN READING

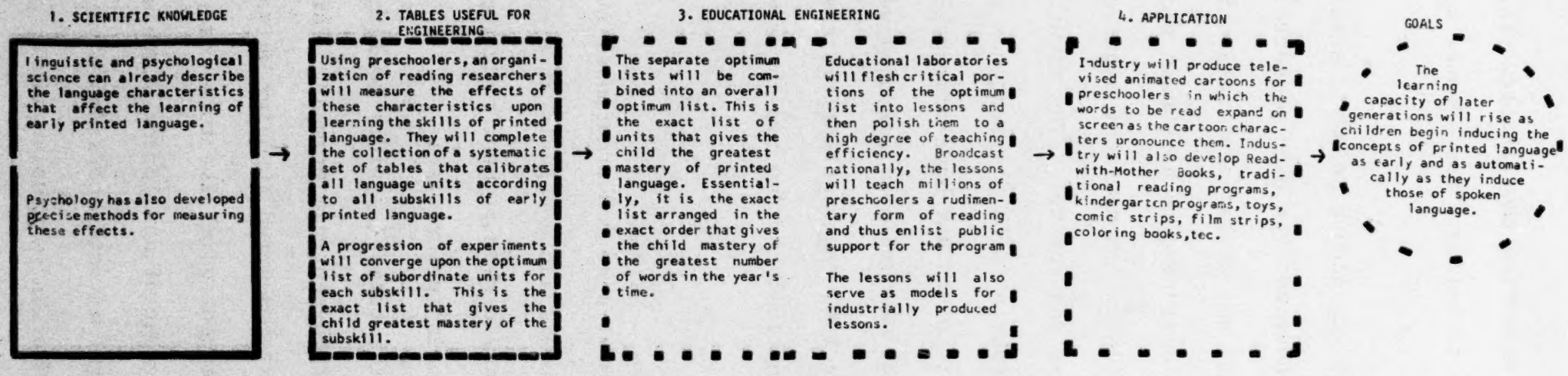
1. SCIENTIFIC KNOWLEDGE
2. TABLES USEFUL FOR ENGINEERING
3. EDUCATIONAL ENGINEERING
4. APPLICATION
GOALS
linguistic and psychological science can already describe the language characteristics that affect the learning of early printed language.
Psychology has also developed precise methods for measuring these effects.
Using preschoolers, an organization of reading researchers will measure the effects of these characteristics upon learning the skills of printed language. They will complete the collection of a systematic set of tables that calibrates all language units according to all subskills of early printed language.
A progression of experiments will converge upon the optimum list of subordinate units for each subskill. This is the exact list that gives the child greatest mastery of the subskill.
The separate optimum lists will be combined into an overall optimum list. This is the exact list of units that gives the child the greatest mastery of printed language. Essentially, it is the exact list arranged in the exact order that gives the child mastery of the greatest number of words in the year's time.
Educational laboratories will flesh critical portions of the optimum list into lessons and then polish them to a high degree of teaching efficiency. Broadcast nationally, the lessons will teach millions of preschoolers a rudimentary form of reading and thus enlist public support for the program
The lessons will also serve as models for industrially produced lessons.
Industry will produce televised animated cartoons for preschoolers in which the words to be read expand on screen as the cartoon characters pronounce them. Industry will also develop Read-with-Mother Books, traditional reading programs, kindergarten programs, toys, comic strips, film strips, coloring books, tec.
The learning capacity of later generations will rise as children begin inducing the concepts of printed language as early and as automatically as they induce those of spoken language.
Syntax can already describe the variables that affect sentence comprehension,
but psychology has not yet developed adequate methods for measuring sentence-comprehension.
After the first measures of sentence comprehension are developed, reading researchers can begin collecting systematic tables that will index the effects of syntactic variables upon sentence comprehension.
After a few tables are available, educational laboratories can begin experimenting with lessons that teach subskills of sentence comprehension
Linguists must develop a multiple-sentence grammar that describes the characteristics that affect multi-sentence comprehension,
and psychologists must develop measures of multiple-sentence comprehension.
Reading researchers can begin conceptualizing experiments that will measure the effects of multiple-sentence variables upon higher-order comprehension.

Fig. 1. Flow charts for developing a reading technology. Note that blocks to the left are prerequisite to those on the right. Note that the upper rows are logically prior to the lower ones. The heaviness of a line represents the dependability of available methods; the breaks in a line represent the percentage of knowledge not yet available. Thus, to reach the goal in the top row, we must fill in three blocks, beginning with Block 2A, measuring the effects of language characteristics upon learning the skills of printed language. The heaviness of the lines shows that most of the necessary methods are already available for setting off a technological advance in the top row.

learning provides precise techniques for measuring the effects. Thus, in this row, the scientific knowledge is adequate to initiate the advance to a technology.

In the second row, however, the first gap occurs in basic scientific knowledge; measures of sentence comprehension have not yet been perfected. There have been sporadic efforts by psychologists and educational researchers to develop such measures, but although individual results have been promising, an adequate set of measures is still not available. Management planning for the bottom row loses still more in distinctness and control. The first gap in this row also occurs in basic scientific knowledge; a multiple-sentence grammar has not yet been developed. The efforts of linguists who have attempted this task suggest that a satisfactory grammar may not be completed for many years. Thus, considerable resources must be invested in long-range scientific research before a technology for defining and achieving the goals of the two lower rows will be possible.

Overall Management Plan. The management plan for a national effort must arouse enthusiasm for its goals, and it should achieve goals at a rate that steadily increases enthusiasm. Thus, it would seem prudent to allocate available resources according to the following priorities:

1. Allocate a modest percentage of the total (say 10%) to linguists for the purpose of developing a multiple-sentence grammar. This is long-range, basic research that is best conducted in major universities.
2. Allocate a considerably higher percentage of the total (say 20%) to behavioral scientists for the purpose of developing a measure of sentence comprehension. If several investigators who have worked in this field were brought together for an exhaustive summer planning

session, they could formulate a research management plan that would produce an adequate set of measures in from three to seven years.

As soon as the first measure is perfected, priorities should be reassigned to allocate additional resources to collecting the systematic tables (Block 2 of Row 2). It is probable that some of these measures will also serve as measures of multiple-sentence comprehension. Although an overall theory of multiple-sentence grammar lies in the future, many of the variables that affect multiple-sentence comprehension can be listed (anaphora, type-token ratio, content word ratio, depth of vocabulary, etc.). Therefore, as soon as the first measures of multiple-sentence comprehension are perfected, priorities should be reassigned to allocate resources to indexing the effects of known variables upon these measures (Block 2 of Row 3). The information will feed back to the left and speed the development of a multiple-sentence grammar.

3. Allocate the majority of the initial resources (70%) to filling in the blocks and reaching the goal for the top row. This is not a modest goal despite its being only one aspect of a management plan that is itself only part of a still more ambitious design. There are three reasons for concentrating most of the initial resources at the top row:

   First, the top row describes skills that are taught to young children and recent research suggests that adult learning capacity can be increased by early training. By engineering reading content to be as learnable as possible and by presenting it as an animated cartoon in which the words spoken by the characters pulsate on screen just as they are pronounced, the Appalachia Educational Laboratory has developed reading material that a two-year-old can enjoy.

Second, in teaching the printed language skills to young children, the technological prerequisites (Blocks 1 and 2) would be available for making the quantum leap from the methods of craftsmanship to the methods of engineering, and the advance to engineering inevitably triggers a rapidly accelerating improvement in cost effectiveness.

Third, teaching preschoolers printed language can be achieved at a trifling cost per child because the animated cartoons can be prepared by the entertainment industry and delivered through the nation's television system in the same fashion as Sesame Street.

The Appalachia cartoons are now being refined to maximize their teaching efficiency. National enthusiasm could be aroused through network broadcasts of these lessons. With adequate advance promotion, they would start preschoolers on a rudimentary form of reading. The results should persuade industry to develop an additional three hundred lessons, permitting a daily broadcast throughout the year. Results to date suggest that it would not be unreasonable to predict the following impact after several years of such broadcasts:

At 40 months	The child would recognize many different words, understand that different word shapes signal different word sounds, have been introduced to the concepts of phonics, spelling, and printing.
At 50 months	Child could read 15 words, be able to sound out a few unfamiliar words with prompting.
At 60 months	Child could read 30-40 words, have a fair understanding of spelling and phonic concepts.
At 70 months	Child could read 100-200 words, be a master of spelling and phonic concepts, be able to sound out unfamiliar words.

A child learns spoken language at such an early age that he cannot remember having learned it; it is a tool to think with. By slight modification of the

animated cartoons the networks are broadcasting every Saturday, the American child could enter school with equal control over the concepts of printed language. At modest cost, a child could reach school age using these powerful intellectual tools as automatically as he uses spoken language.

Summary. A national commitment should be made to establish a series of Educational Experiment Stations analogous to agricultural experiment stations. The stations would perform for education the same sort of field experiments that triggered the steady increase in crop production after the 1830's.

The first station would be an Educational Experiment Station in Reading, and its first assignment would be to teach printed language to young children. This would be the initial thrust because: (a) science has an adequate fund of knowledge about teaching such skills, (b) the entertainment industry has an equally adequate fund of resources for teaching them, (c) a modest expenditure--five to ten million dollars--can build a bridge between the two and get a technological advance under way that will raise the learning capacity of the American child, enabling him to use the intellectual tools of printed language as automatically as he uses those of spoken language.

Once the effort is completed, exactly the same plan can be followed for an Educational Experiment Station in Mathematics--and then perhaps one in problem-solving.

The rest of the paper is devoted to the management plan for the top row. One section is devoted to each block or partial block. Most sections end with a cumulative summary that discusses the rationale of the plan through the block.

BLOCK 1. SCIENTIFIC KNOWLEDGE

The scientific knowledge that is presently available is sufficient to launch a technology for teaching the early printed language skills. Most of those skills are listed in Figure 2, but the figure is not intended to be a final analysis of printed language. Its major purpose was to suggest the scaling studies being performed in Block 2A.

Figure 2 is divided and the left-hand side represents stimulus variables--language characteristics that affect reading behavior. There is solid scientific knowledge about these variables: vocabulary studies, linguistic theories of phonology and morphology, the typographical experiments of psychologists such as Tinker, developmental studies such as those of Templin or Loban, and so on.

The response side of the figure represents psychological techniques for measuring reading skills. The skills can be factored into paired-associate learning or concept induction, and psychologists stretching back to Ebbinghaus have been developing sharp methods for measuring and analyzing such skills.

Figure 2 can be analyzed in finer detail because the majority of the subskills can be conceptualized as paired-associate learning, and McGuire (1961) has shown that this form of learning can be analyzed into three stages: (a) stimulus learning in which the stimulus is encoded and differentiated from the other stimuli, (b) response learning that involves both the integration of a particular response and the discrimination between responses, and (c) learning to make the response to the encoded version of the stimulus. Battig (1968) has presented an even more detailed analysis.

Stimulus	Response
1. Child perceives printed word as a whole.	He says word; he recognizes whole word-shape.
2. Child sees letter.	He says phoneme.
3. Child hears phoneme.	He gives letter.
4. Child hears phoneme.	He prints letter.
SOUNDING OUT A WORD	
5. Child sees printed word.	He segments into sequence of letters, and/or syllables, and/or morphemes.
6. Sequence of letters, and/or syllables, and/or morphemes.	He maps into (says) sequence of phonemes, syllables, morphemes.
7. Child hears sequence of isolated sounds (that he says himself).	He blends into word-sound.
SPELLING A WORD	
8. Child hears word.	He segments into sequence of phonemes.
9. Sequence of phonemes (that he says himself).	Maps into sequence of letters.

Fig. 2. Partial list of subskills involved in early printed language.

BLOCK 2A. TRANSFORMING SCIENTIFIC KNOWLEDGE INTO USEFUL TABLES

In Block 2A, the same general strategies employed by agricultural experiment stations to transform chemical knowledge into tables useful for agriculture are being used to transform scientific knowledge from Block 1 into tables useful for educational engineering.[2] Most of the experiments that generated insights into reading were performed upon college sophomores memorizing lists of discrete items drawn from artificial language populations. To transform those gross insights into tables useful for engineering, the experiments are being replicated upon young children learning reading responses--upon six-year-olds memorizing the sounds of letters, upon children learning spelling irregularities, and so on.

The steps for collecting these tables are straightforward and have been described in detail (Coleman, in press). The first step is to analyze the complex hierarchy of skills that constitute printed language into subskills, each of which is simple enough to yield to experimental measurement (Figure 2). Using kindergarteners, scaling studies are then performed, each of which calibrates language units according to ease of learning them in a subskill. In short, children are used as calipers to calibrate the materials that compose the reading program.[3]

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[2]This research is supported by NSF Grant GB 3535 and by a grant from the Committee on Basic Research in Education, OEG-7-9-530279-0122-(010).

[3]These calibrations are being collected by a number of individuals who recently became part of a special interest group on reading research within the American Educational Research Association.

The detail necessary for the present paper can be given by summarizing four broadband experiments. The first scales common words according to the ease with which the child learns to read them. The second scales letters according to the ease with which the child learns the sounds associated with them. The third scales the sounds according to their phonic blendability. The fourth scales letters according to ease of printing. Once a number of such scales are organized into a systematic set, the engineering described in later blocks will be possible.

Whole Word Learning. Subskill 1 is look-and-say learning of whole words. Jones (1968) and Coleman (in press) have reported data that scale the common words for learnability. A paired-associate technique was used to teach the child to read words, the printed word being the stimulus and pronouncing it being the response. Each word was then scaled by averaging its errors. The sort of data they collected is presented in an oversimplified fashion by Sub-block 1 in Block 2 (See Figure 3). Note that some words are several times as difficult to learn as others.

Thus, abstract scientific knowledge has been transformed into specific tables that a technician could use in choosing words for a beginning program in reading. The tables show which words are easiest to learn, the ones to use at the beginning when the child is struggling with the basic concept of reading. The tables also show which words will necessitate extra effort when they are introduced. Of more scientific importance, the tables suggests follow-up studies that may reveal reasons why the words rank-order as they do.

BLOCK 1. SCIENTIFIC KNOWLEDGE

Stimulus	Response
1. Child perceives printed word as a whole.	He says word; he recognizes whole word-shape.
TYPOGRAPHICAL, SEMANTIC, AND LINGUISTIC DESCRIPTION OF THE CHARACTERISTICS THAT AFFECT LOOK-SAY LEARNING OF WORDS	
2. Child sees letter	He says sound
PHONOLOGICAL AND TYPOGRAPHICAL DESCRIPTION OF THE CHARACTERISTICS THAT AFFECT LEARNING THE SOUNDS OF THE LETTERS	
⋮	
4. Child hears sound	He prints letter
DEVELOPMENTAL STUDIES OF PERCEPTUAL MOTOR SKILLS	
⋮	
7. Child hears sequence of isolated sounds	He blends into word
PHONOLOGICAL DESCRIPTION OF THE CHARACTERISTICS THAT AFFECT BLENDING	

BLOCK 2A. SCIENTIFIC KNOWLEDGE TRANSFORMED INTO TABLES USEFUL FOR ENGINEERING

Stimulus		Response
1. Child sees printed word		He pronounces word
	0	X
	kitten	X
	up	X
	cow	X
	Bill	XX
	⋮	⋮
	make	XXXXXXXXXXXX
	us	XXXXXXXXXXXXX
	⋮	⋮
	then	XXXXXXXXXXXXXXXXXXXXXXX
2. Child sees letter		He says sound
	s	XXXX
	ie	XXXXX
	⋮	⋮
	aw	XXXXXXXXXXXXXXXXXXXXXXX
⋮		
4. Child hears sound		He prints letter
	l	X
	o	X
	⋮	⋮
	u	XXXXXXX
⋮		
7. Child hears isolated sounds		He blends into word
	ou t	XX
	u p	XXX
	⋮	⋮
	l aw	XXXXXXXXXXXXXXXXXX

Fig. 3. A small sample of the many tables that will be collected in Block 2A. The X's stand for average number of errors to criterion. Each language unit is scaled according to the ease of learning it in one subskill.

Letter-Sound Associations. Using a paired-associate task in which the letter was the stimulus and pronouncing its sound was the response, Bridge (1968) performed an experiment that rank-orders 35 letters and letter combinations according to the ease with which children learn their sounds (Subskill 2). Sub-block 2 of Figure 3 illustrates the sort of results that he and others have reported.

Thus, these experiments also translate general scientific insights into specific tables that a technician can use in designing a reading program. The tables can be used to select the first letter-sound associations to teach in a phonics program, and in addition, they suggest the same kind of basic studies that were mentioned for words.

Phonic Blending. Laumbach (1968) scaled the two-sound words of English according to phonic blendability. As a stimulus, she pronounced two isolated sounds for the child /a,t/ and his task was to pronounce the word (at). Laumbach made the same general finding presented above, i.e., there are large differences--as high as 10 to 1--in the blendability of different phoneme combinations and the same pattern holds true for most children. Some of the more important data from her experiment and similar ones are summarized in Sub-block 7 of Figure 3.

Printing Letters. Jones (1968) and Karagiaouris (1969) rank-ordered the lower-case letters according to ease of printing. These investigators gave each child a letter and asked him to copy it; after he had copied a set he was given instruction and further practice. The next day the procedure was repeated, and so on for a number of days. The sort of scalings they reported are illustrated in Sub-block 4 of Figure 3.

Summary. In Block 2A, the task is to transform the general scientific insights of Block 1 into tables useful for engineering. Using kindergarteners, scaling studies are being performed, each of which calibrates language units according to the ease of learning them in a subskill of printed language. That is, children are being used as calipers to scale the materials used in the reading program.

Tables such as those in Figure 3 are prerequisite to the engineering experiments in the following blocks; however, it is important to note that these tables have uses outside the laboratory. Just as studies of plant nutrition generate tables that can be used by a practicing farmer, these tables can be used by personnel with no training in linguistics or psychology--by teachers, writers, and editors.

In 1970, a special interest group for basic research in reading was formed within the American Educational Research Association. Part of that group is establishing administrative machinery for collecting such tables. Ultimately, however, the responsibility for amassing this information must be assigned to an institution similar to an agricultural experiment station, an Educational Experiment Station in Reading. At present, the researchers with the appropriate skills are concentrated in universities, but universities do not have the support staff or value system that stimulates this kind of data collection.

BLOCK 2B. THE OPTIMUM LISTS

In Block 2B, the task is to discover the optimum list for each subskill--the particular list of language units from which the child can most efficiently master the subskill. That is, a child masters a subskill by mastering a list of subordinate items; the larger the list, the more completely the subskill has been mastered. There is some list of items that gives greatest mastery in a given time. Note that this is a higher-order definition of "ease of learning." In 2A, an individual language unit was scaled acording to the ease of learning it (Figure 3). In 2B, long lists of units are selected and arranged to make the subskill itself easy to learn.

The first step in establishing the optimum list is to select a tentative list of language units for the subskill by considering each item's productivity and ease of learning. For example, in selecting words for the subskill of reading sentences, certain words such as the, of, but, and the like must be included because of their productivity; they occur in large numbers of sentences. On the other hand, nouns, verbs, and adjectives can be selected almost entirely according to ease of learning. In short, the first step is to consider tables that rank units according to learnability together with tables that rank them according to productivity (or frequency of occurrence).

After selecting a tentative list, the second step is to arrange them in the order of their introduction. At the beginning, frequently used items (f is pronounced /f/) are more useful to the child than uncommon ones (gh is pronounced /f/). Easily learned tasks (discriminating w from s) will be taught before the difficult ones (discriminating b from d). More generally, the optimum list will probably begin with the most usable and most learnable items. By considering

usefulness and learnability in sequencing what is taught the child, each burden of learning imposed upon him will deliver maximum yield in words that can be used in actual reading.

Far more important, the optimum list will be designed to reduce concept induction time. For instance, the concepts underlying phonics may take several years to induce from the usual list of irregularly spelled words, but only a few weeks to induce if the words are systematically selected from the tables of Block 2A. The magnitude of the gain from logical selection should not be underestimated. The experience of school children shows that it is extremely difficult to induce the concepts of phonics from a list such as here, come, Tom, write, play, etc. It is fairly easy with words selected from the tables illustrated by Sub-block 7 of Figure 3 (e.g., it, at, up, us, see, etc.).

After optimum lists are established for individual subskills, they will be combined to establish the overall optimum list--the list from which the child can most efficiently induce the overall concepts of printed language. The optimum lists for the following subskills will be established first because they are the most critical for determining the overall list:

1. The optimum list of words for teaching the child to read sentences,
2. the optimum list of letters and blends for teaching phonic blending,
3. the optimum list of spelling qualifications for teaching the patterns of English spelling.

The optimum list of words for teaching the child to read sentences. A major problem in establishing all optimum lists is deciding the relative importance of learnability to productivity. All the common words have been scaled as to learnability (Sub-block 1 of Block 2) and productivity (frequency of usage tables). An investigator could sequence the items for two tentative lists with

two multiple regression equations that weight each item's learnability measure to its productivity measure at 4 to 1 and 1 to 4. The two sequences would then be administered to two matched groups of preschool children. Each child would learn the words on his list from flashcards--as many as he could learn each day--and also read them in sentences, perhaps 100-200 words of text per day.

This experiment can be as tightly controlled as those of 2A. In fact, it will be quite similar to the traditional paired-associate experiment. The word--whether read from a flashcard or in a sentence--will be the stimulus and the child's pronunciation of it will be the response. Every response he makes will be recorded and reinforced.

Some possible results are given in Figure 4. If such results occurred, they would indicate that the optimum weighting changes over time; productivity should be weighted most heavily at first, but learnability becomes progressively more important during the later weeks. A series of such experiments would refine the technique, then converge upon the optimum list. For example, the better

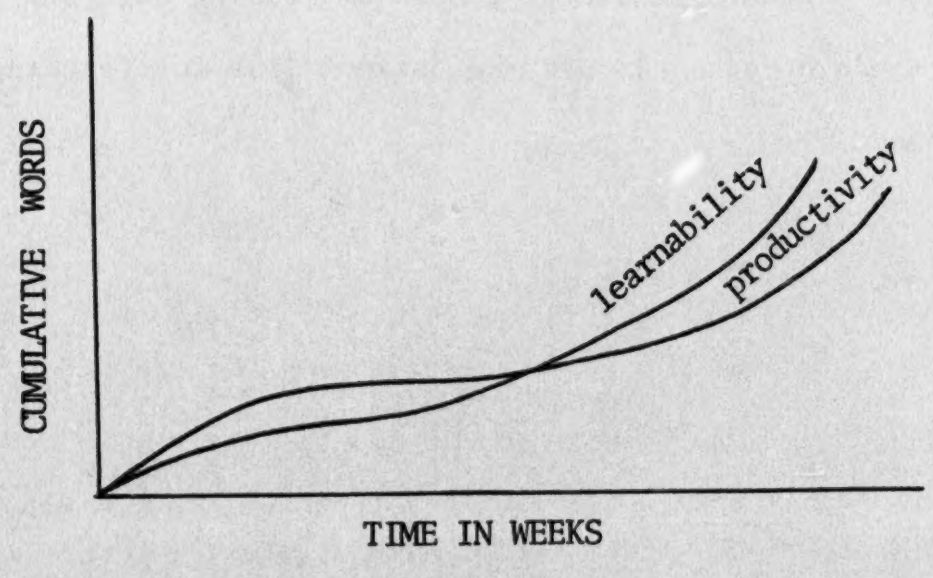

Figure 4. Possible curves from a hypothetical experiment that compares a tentative list favoring productivity to one favoring learnability.

parts of the lists in Figure 4 would be combined in several ways that would be compared in a second experiment. The findings of that experiment would be used to design even more effective lists, and so on.

Analogous progressions of experiments would converge upon the optimum lists for other subskills, the subskills under consideration determining the stimuli and the response measures. As soon as a few optimum lists are available, they can be experimentally combined as described in Block 3A to design the framework of the year's program.

Summary. Three points should be emphasized: First, note that it would be impossible to converge upon an optimum list until one has performed the simpler experiments in 2A that scale individual items according to the subskill. Second, note that progressions of experiments are necessary in 2B. Furthermore, each experiment in the progression is far more expensive than those in 2A. They last longer, up to three weeks. The stimuli are not unordered slides, but long, sequenced lists. The responses are more complicated, more similar to actual reading. Third, the findings of 2B are useful outside the laboratory. In fact, they are more directly generalizable to classroom reading behavior than those of 2A. Teachers could certainly use the optimum list for teaching phonic blending, for example.

BLOCK 3A. ESTABLISHING THE FRAMEWORK FOR THE YEAR'S PROGRAM: THE OVERALL OPTIMUM LIST

In Block 3A, the task is to combine the separate optimum lists and establish the overall optimum list. The overall list is the framework for the year's program--the complete list of items that will be taught arranged in their order of introduction. A child masters printed language by mastering this list of subskills and subordinate items, the larger and more productive the list, the greater his mastery. The task in 3A is to converge upon the particular list that gives him greatest mastery in a year's time.

Failure to establish the optimum list is a major shortcoming in the present procedures for developing an educational product. The best current strategy uses a team of instructional programmers advised by subject matter experts, and at present, the team relies largely upon experience and unrefined scientific knowledge--knowledge from Block 1 that in the main was gleaned from experiments using nonsense syllables or similar artificial populations. By making calculated guesses from that knowledge base, the team lists the behavioral objectives of the program. But they have no effective technique for selecting the items that constitute the objectives. The most effective words, sounds, etc. cannot be selected with findings from experiments that used unrepresentative populations; the items themselves must be calibrated as discussed in Block 2A.

The objectives--actually the items that constitute them--form the framework of the program, and it is only good sense to demand that one build the strongest framework that current methods permit before fleshing it into a

finished program.[4] After the framework is developed into expensive lessons, finding a basic weakness in it is as frustrating as finding a defect in the foundation of a skyscraper after the interior decorating is finished. The only honest thing to do is tear it down and start over. There is no effective way to remodel lessons that were built from the wrong words and sounds.

A major purpose of the present paper is to list the steps and the R & D system that could build a strong framework. The first and second steps have already been discussed. The first step is to calibrate the individual language units and the second is to arrange them in the lists from which the the child can most efficiently induce an individual subskill. The third step will be to perform a progression of experiments that combines individual lists and converges upon the optimum list for inducing the overall concepts of printed language. In establishing the overall optimum list, one considers all subskills and all forms of learnability, weights them as to overall importance, then selects and orders the lists of subordinate items (words, letters, etc.) so as to give the child mastery of a maximum number of items in the year's time. The result will be a list of behavioral objectives, but an optimum list that differs qualitatively from those that are determined by current practice.

In the third step, one first combines pairs of individual optimum lists from Block 2A. The following two would establish the broad outlines of the overall list:

1. Combine the optimum list for teaching the sounds of letters with the optimum list for teaching blending. This will establish

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[4]After the lesson is finished, it is current practice to test it with the corrective feedback mechanism, but it is wasteful to build a finished lesson from the wrong items, and in addition, the feedback mechanism is not effective in detecting a poor choice of items.

the most efficient sequence of letters and blends for teaching phonics.

2. Then combine the optimum list for teaching phonics with the optimum list for teaching words. This will establish the ratio of look-say words introduced per week to words that are sounded out. Obviously, that ratio will change as learning progresses.

Several generations of longitudinal experiments, each extending over several weeks, will converge upon these ratios. Although the experiments will teach a skeletal form of reading, they too can be as tightly controlled as laboratory studies of paired associate learning.

Although it was not described as such, a progression of three experiments I performed several years ago illustrated a technique for choosing among lists and gradually converging upon the optimum one (Coleman, 1967). In the first of the three experiments, a list designed for pure phonics was compared to one of equal length designed for pure look-say. The experiment used matched pairs of five-year-olds, one member of each pair being taught from the list designed for phonics and the other being taught from the list designed for look-say. Each child was taught individually for approximately 30 minutes each day.

The influence of the teacher was reduced to a minimum by extrinsically rewarding the child for each of his approximately 80 responses. The child was trying to earn a toy by working for marbles. At the beginning of each subtask, which corresponded closely to the subskills of Figure 2, he was given a handful of marbles--one for each response in that subtask. For each incorrect response, the child was punished by making him give back a marble. For each correct response, he was rewarded by being allowed to place a marble in a transparent

jar. When the jar was filled, he won a toy. The 80 odd responses were to eight tasks:

1. The child tried to recognize seven words presented individually. A word was presented for 12 seconds and if the child made no response, he was told the pronunciation of the word and a marble was taken away. After he recognized a word correctly on three separate days, that word was dropped and a new one was added.
2. He read approximately 40 words in a story. He started Task 2 with 20 marbles, one being taken from him for each word he read incorrectly. After finishing, he placed his remaining marbles in his transparent jar.

Each child was tested on approximately 40 other responses that were analogous to the subordinate associations of Figure 3. The results of the three experiments illustrate how one converges toward a list that is generated by an optimum combination of phonics and look-say:

Exp. I. After two weeks of teaching several matched pairs of children, it became clear that the list designed for pure phonics overemphasized phonics and spelling to the extent that it disrupted the memorization of whole word shapes. Its words were generated from only seven lower case letters (s, m, l, n, ee, a, i). From these seven letters, see, mee, lee, al, am, an, ann, sam, sal, seem, man, lass, lam, sis, miss, ill, mill, and min were generated. Since the child need learn only seven letter-sound pairs, I had thought it would be ridiculously easy to teach him this list. Such was not the case. It was extremely difficult for a beginner to discriminate the word shapes from one another; they were too similar. In the second place, these words--and any other

list generated from a restricted number of letters--contain a number of unfamiliar words; their degree of response availability is low. For these two reasons, the memorization of whole word shapes was very difficult and the list was hard to learn. It seems that no matter how much phonics and spelling are emphasized, actual reading involves a large amount of whole-word memorization.

Exp. II. By using two more letters, another list was generated composed of words that were considerably less similar to one another and that were more commonly used. The average frequency of usage according to Rinsland (1945) was 2592 per word compared to an average of 3432 for the list designed for pure look-say. The second list, which considered both phonics and look-say, was compared to the list that considered look-say alone in another matched-pairs experiment, and it was probably easier to learn. It was certainly easier as far as spelling and phonics were concerned, but difficulties it caused in comprehension showed that it was still far from the optimum list.

Exp. III. By using a few more letters, a list was generated that further increased discriminability and mean frequency of usage. This list, which also considered both phonics and look-say, was mastered in considerably less time than the one of equal length that considered look-say alone.

Except for the books, this experimental technique permits an inexpensive format. The cost of modifying the books can be kept within bounds by having part of the book read by the experimenter, the child only reading the part relevant to the list being tested. The rest of the stimuli are flashcards, and thus, fundamental modifications can be made in the list at slight expense. In short, with a few refinements, a technique for converging upon the overall list is already available. Obviously, depending upon which combination of

individual optimum lists are being considered, the stimuli and responses will differ slightly from the above progression.

Summary. In Block 3A, the task is to conduct a progression of experiments that gradually converges upon the optimum list--the list from which the child can most efficiently induce the overall concepts of printed language. With a few qualifications, this is the list that gives him mastery of a maximum number of words in the year's time.

An R & D system can converge upon the optimum list by conducting experiments in the following sequence: First, a base of scientific knowledge must be available in Block 1. Second, in Block 2A, this knowledge must be transformed into tables that scale all items according to all relevant subskills. Third, in Block 2B, these scalings are used to establish optimum lists for the separate subskills; long lists of units are selected and arranged to make the subskill itself easy to learn. Finally, in Block 3A, the overall list is converged upon by experiments that first combine pairs of optimum lists and gradually progress to experiments that consider larger combinations of them.

It is worthwhile to note that as the flowchart moves to the right, the experiments are becoming more directly generalizable to the everyday behavior that is the goal of an R & D management plan. As the flowchart moves to the right, the responses of each child will be collected for longer periods of time. The experiments of Block 1 typically last for 50 minutes, but the experiments at the end of Block 3A last for many weeks and teach a rudimentary form of reading. At the same time, the stimuli become progressively more elaborate. The stimuli of Block 2A are unordered slides and flashcards, but those of Block 2B are long, rigidly sequenced lists, and those of Block 3A are skeletal reading systems.

The point for R & D planning is this: as the flowchart moves to the right, the cost of experiments increases in a geometric progression. It is wasteful to spend millions of dollars developing a finished reading program before the overall list has been approximated to the degree that current technology allows. It is almost as wasteful to try to establish an overall list before the separate optimum lists have been established, or to attempt to establish these before the individual productivity and learnability of the different language units have been established. This categorical timetable should be interpreted in relative terms, of course. Small-scale, tentative work can be initiated in blocks on the right as soon as efforts to their left start producing usable information.

BLOCK 3B. POLISHING PROTOTYPE LESSONS

As soon as a reasonable approximation to the optimum list for the year is established, critical parts of it can be fleshed into lessons which will then be refined into maximally efficient teaching instruments. The lessons will serve as models from which industry will develop the daily broadcast. Most of the polishing in 3B will be done with the corrective feedback mechanism, but the materials will be designed so that more powerful engineering techniques can be used if fundamental problems appear.

Another task in 3B is to articulate the goal in a way that enlists public support and establishes the goal as a national commitment. Trial broadcasts of the first animated cartoons have introduced three-year-olds to a rudimentary form of reading. With imaginative advance preparation, network broadcasts would introduce ten to fifteen million preschool children to the skill. This demonstration would not only enlist support from the general public; the financial promise from a market of this size would channel considerable industrial resources into the effort.

Description of the Prototype Lessons. The Appalachia Educational Laboratory is already producing animated cartoons to provide models for the first lessons of the year's program. The first cartoon begins with material simple enough that a preschooler can learn to read it immediately, after only a few minutes instruction. In these cartoons, the words to be read by the child expand on the screen just as the cartoon character pronounces them. There is a progression of 20 lessons that increases in difficulty so gradually that a preschooler teaches himself as he entertains himself.

Technique for Refining the Prototype. The Appalachia Laboratory is using a technique to polish its first 20 lessons that can also serve as a model.

To adapt the 20 lessons to engineering, the laboratory sliced them into individually testable strata that correspond to the subskills of printed language. Each of the 20 lessons is assembled on videotape as a coherent whole, of course, but originally the entire program was stratified into many reels of animated film, each corresponding to a Subskill of Figure 2.[5] Straightforward paired-associate techniques can measure the teaching efficiency of each reel or of each 10-to-20 second segment of the reel. Each segment corresponds to a subordinate item such as those of Block 2 in Figure 3.

The prototypes lessons are being presented to children and detailed records kept of the responses. When the records show that the children are having difficulty with particular strata or particular segments, improved versions are presented to a second cycle of children and so on. Using the laboratory techniques of the paired-associate experiment, it is possible to plot hundreds of day-by-day learning curves for a child,[6] (for example, a curve plotting percentage of errors against time when the child is asked to blend the sounds /u,p/ into the word up).

After the 20 lessons of the Appalachia program are perfected, they will provide part of the model that industry needs to elaborate the optimum list into sufficient cartoons for a daily broadcast throughout the year. Undoubtedly other critical parts of the list must be fleshed into lessons, however. The program for the year will encounter problems that are not considered during the first 20 days--spelling qualifications, for example, or the reading of books other than cartoon books.

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[5]For example, Subskill 2 is learning the sounds of the letters. In a reel corresponding to this subskill, each of five letters (s, u, p, i, t) animates, pronounces its own sound, and sings a song about its sound.

[6]The article described in Block 3A (Coleman, 1967) reports a use of paired-associate techniques specifically oriented toward plotting reading responses of preschool children.

Note that the corrective feedback mechanism is being used as a polishing tool only. Like a razor strop, this tool does not cut deep. If, like a glob of pig iron, the initial program had been an unanalyzable piece of junk, 10 years of polishing with the feedback mechanism would yield no more than shiny junk. An engineer needs a way to select the most effective list of subordinate items and he needs powerful research tools if he is to cut into a program and make improvements in its basic structure. The very reason the management plan started with the top row in the flowchart is because the way to select items and the powerful tools are available. For this restricted area of language, the scientific insights of Block 1, after they are augmented by the systematic tables of Block 2 and the engineering experiments of Block 3A, provide analytical tools that slice the program into such thin components that a polishing tool can be brought to bear on almost all the flaws that remain.

BLOCK 4. INDUSTRY AND APPLICATION

In Block 4, the optimum list will be used to develop some 300 cartoon lessons modeled after those of Block 3A. The entertainment industry has a monopoly on certain talents that are needed to produce quality animated cartoons and the publishing industry has a monopoly on other talents that are needed in the project. Both industries are energized by profit. Any plan of national scope that fails to take these elementary facts into account runs a high risk of mediocrity; both talent pools are absolutely necessary, and in order to use them, the products must show a profit. The specific products that will survive that acid test are hard to predict, but the following are likely candidates:

Sponsored Television Program. This television series would be advertising in a new sense of the word. As it was entertaining the child, it would be preparing him to benefit from a particular set of educational products. It would resemble and supplement Sesame Street.

Reading suggests disciplined eye movements marching across the page of a book. This definition of reading requires a mature child with a considerable history of pre-reading experience, but the definition has been outdated since the first animated cartoon was broadcast over television. The Appalachia Laboratory has shown that it can bring the concepts of reading within the capacity of three-year-olds with animation and television; simpler and more refined lessons can probably bring them within the capacity of two-year-olds. Examples of how animation is used in the 20 lessons to illustrate basic concepts of reading follow:

A. The fundamental concept of reading is that printed words tell the child what to say and different words tell him different things to say. With this skill alone, he can begin reading. A cartoonist can write a story with a single word. For example, the laboratory's first lesson builds an animated cartoon around the story of the Little Red Hen that used the single word "no." Many two-year-olds enjoy the cartoon and respond appropriately as "no" expands on the screen when it is spoken by the Little Hen's lazy friends.

An animated cartoon can be written around a song so that a little comic opera results. Very young children enjoy singing the song as the words expand with the music.

B. Letters also tell the child to say sounds and different letters tell him to say different sounds. There are lesson segments in which the letters animate and say their own sounds. For example, a face appears in the letter o and pronounces its own sound. Then the lips form a smaller o, which expands and zooms out of the screen. The letter s fades into a snake that pronounces the sound. More generally, animation is used so that each letter becomes a trigger for a visual image that in turn triggers the sound. Compare this device to Paivio's (1969) recent work on imagery as a mnemonic.

C. Letters are combined to spell words. Hundreds of times in the program the individual letters of the word appear on screen and then dance together to blend into the word.

D. Sounds are combined to say words. Letters of words selected from the tables of Block 2 because they are easy to blend (us, up, it) appear individually on screen. They say their own sounds as they gradually jump together and blend into a word. Figure 6 is a

Fig. 5. Excerpts from a Read-with-Mother Book designed to accompany the first lesson.

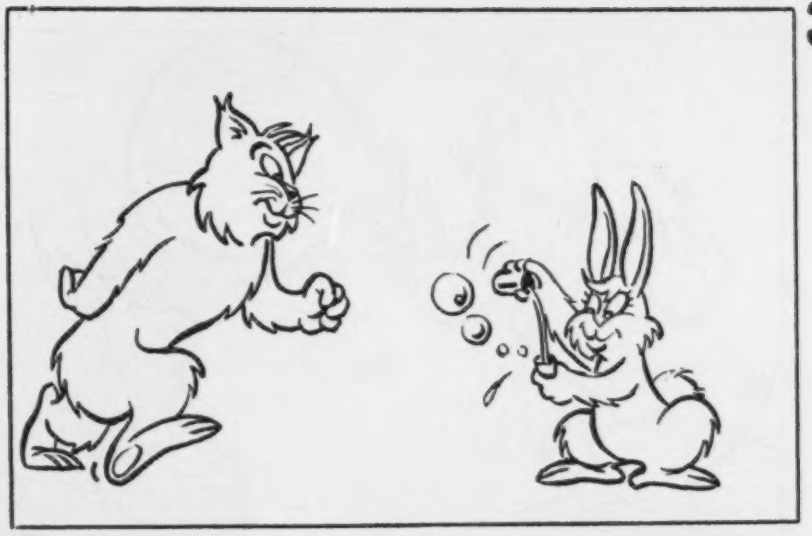
storyboard for a sound-out, animated cartoon. These animated cartoons tell a story built around the images in B, which, if the child remembers the plot, enables him to sound out the word. Compare this mnemonic device with the use of stories as an aid to memory (Bower and Clark, 1969). Note that almost all the concepts of printed language are presented as entertainment in the form of easily remembered, animated cartoon narratives.

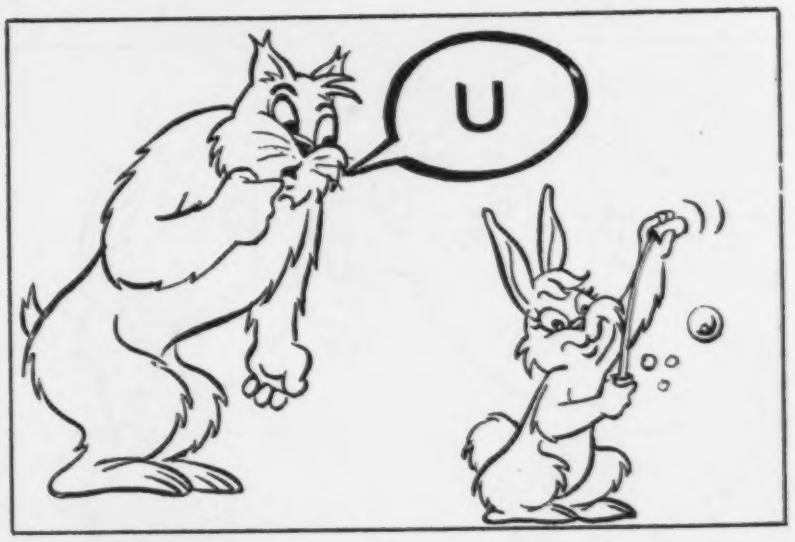
E. The techniques used for illustrating the concepts that printed words can be analyzed into letters and that spoken words can be analyzed into sounds should be obvious from C and D.

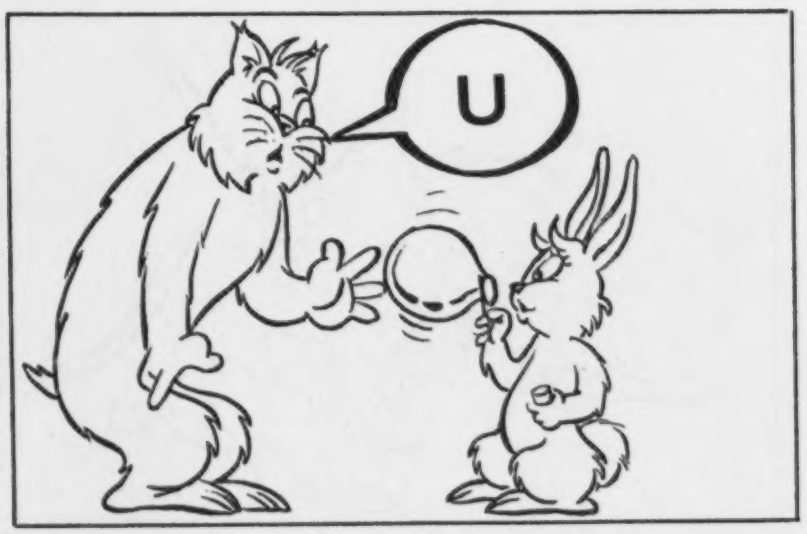
If a child had been watching such cartoons throughout his preschool years, he would enter the first grade using the concepts of printed language as automatically as he uses those of spoken language. The child need have no difficulty with reading concepts. Using the tables of Block 2A, the printed language that he is to process through vision can be kept at a far simpler level than the spoken language he is processing through hearing. Actually the child has most difficulty with mechanical skills such as turning pages, focusing upon the pertinent details, focusing upon them in the correct order, always reading from left-to-right, etc. All these problems can be eliminated with an animation camera.

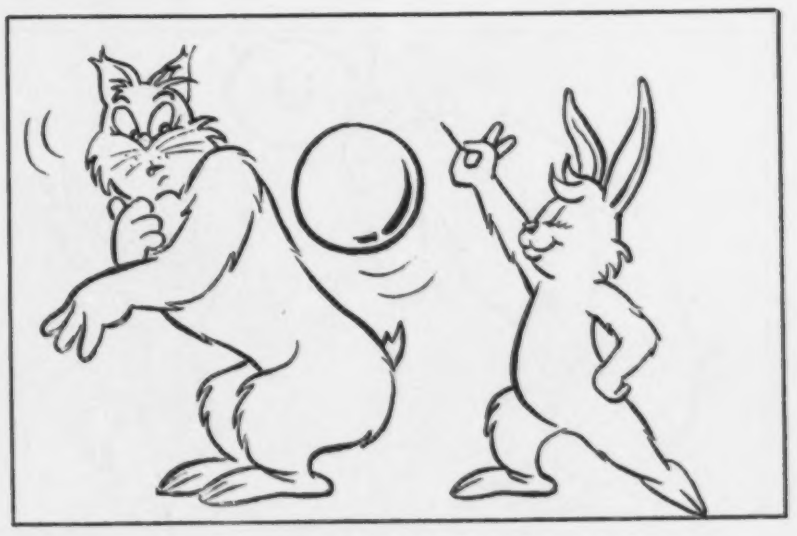
Such a television program should not lack for sponsors. It would be advertising of singular effectiveness. As the cartoons taught the child certain skills, they would be turning him into a consumer of certain educational products. There is nothing sinister in this since the products would enhance the instructional value of the television program. For instance:

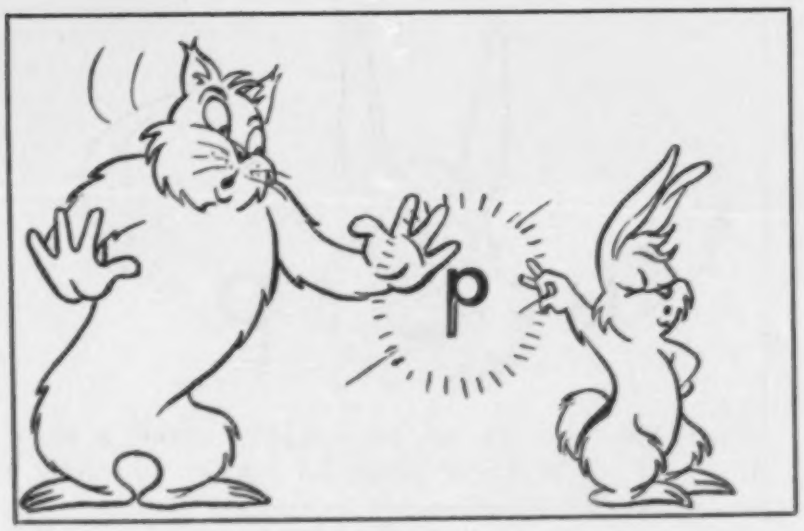
Read-With-Mother Books. Figure 5 illustrates a book that a three-year-old could help read after seeing the first program. It is an intermediate

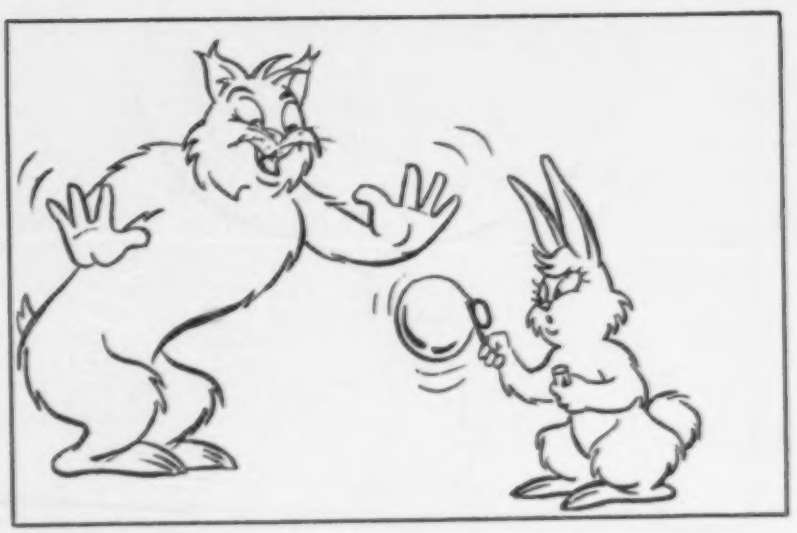












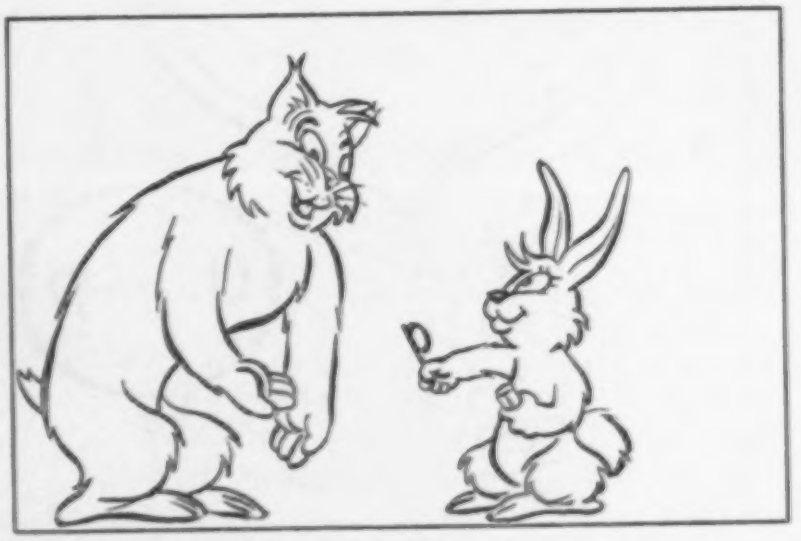
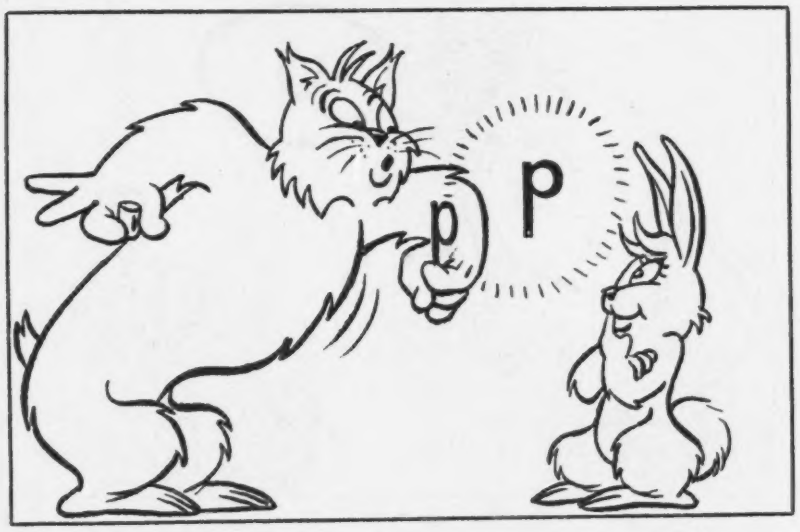
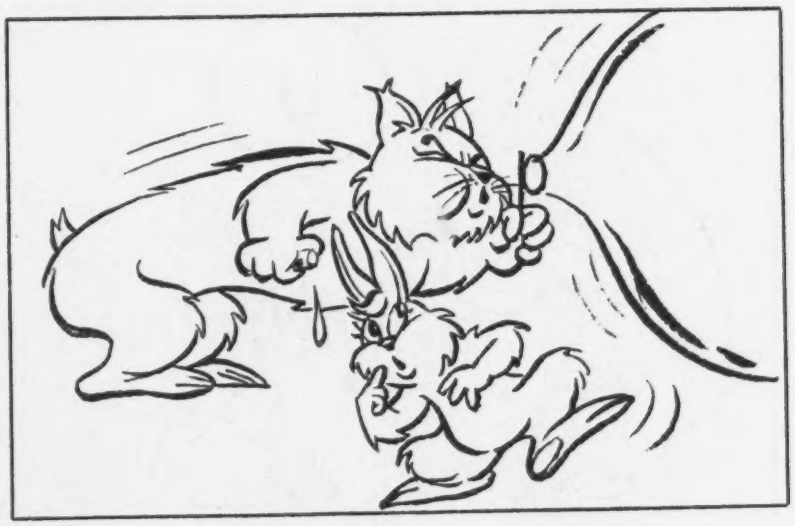
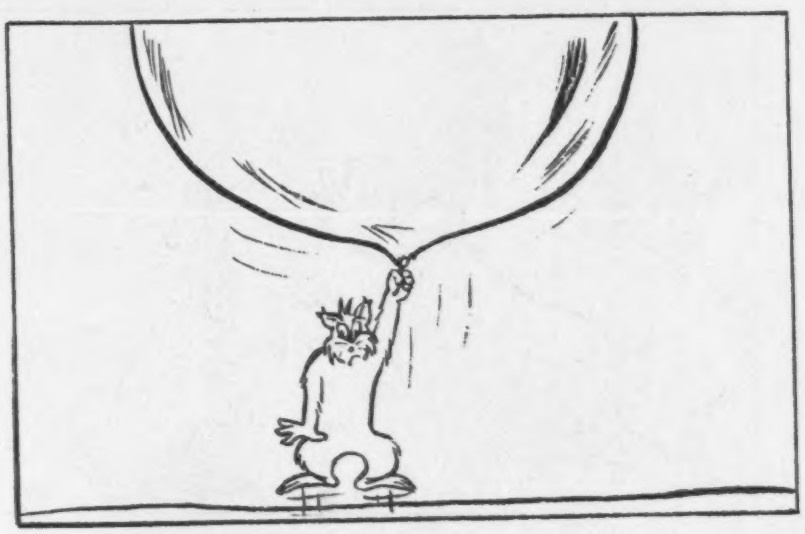
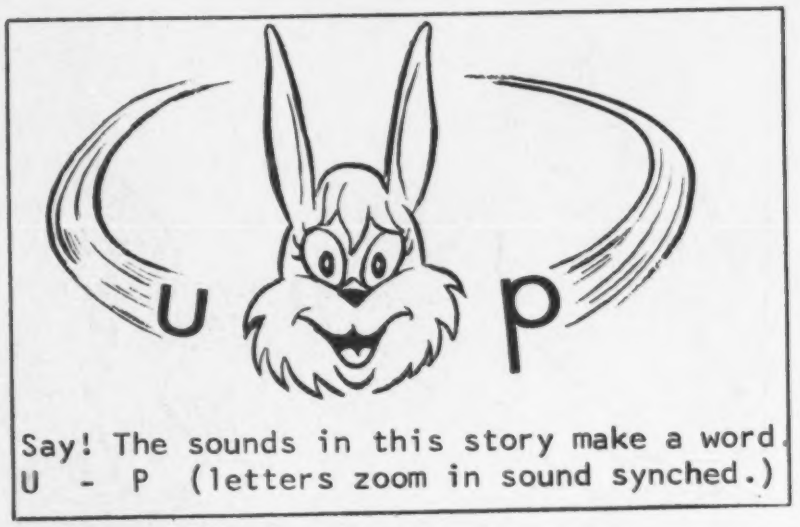


Fig. 6. Excerpts from a storyboard from which a sound-out animated cartoon was developed. The storyboard is almost identical to the cartoon book that accompanies the lesson.

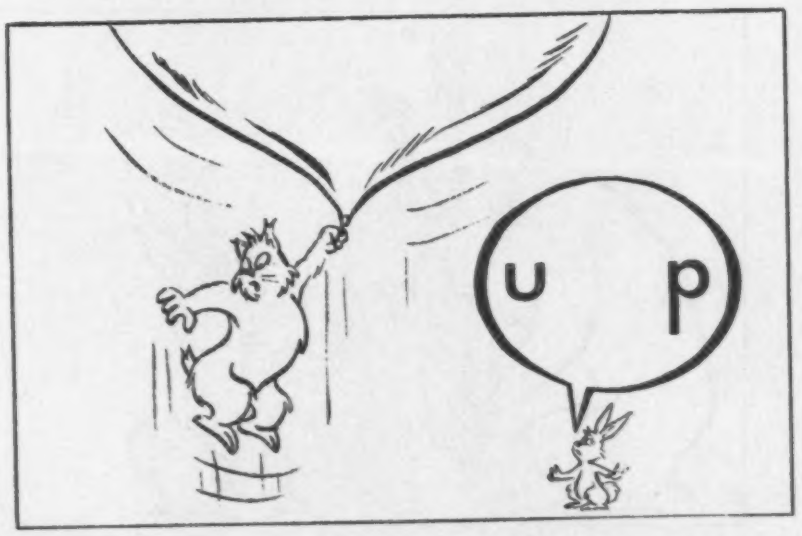


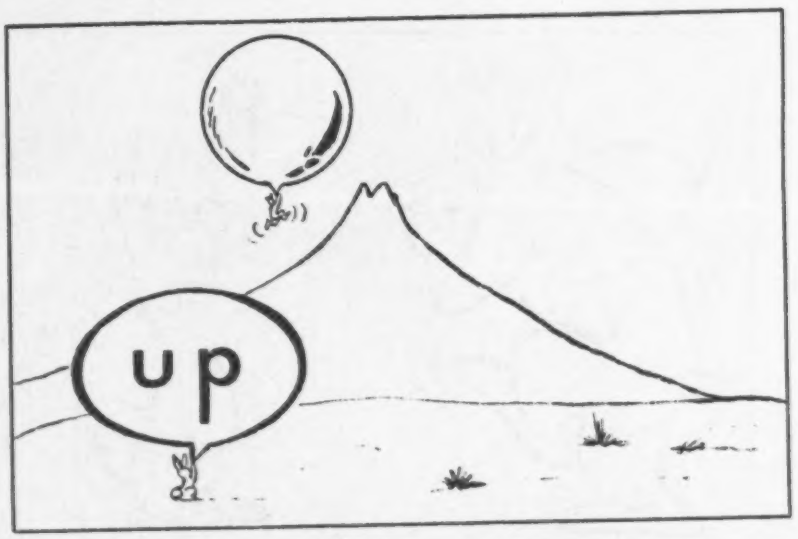






Say! The sounds in this story make a word.
U - P (letters zoom in sound synched.)





Big Bad Bobcat is going ... U P, U P, U P, U P, U P, UP

step between reading to a child and having him read to you. An adult reads the small print, of course, and the child reads the large print.

Phonic Books. Figure 6 illustrates a book that accompanies the sound-out cartoons and helps teach the child to sound out a word.

Educational Toys. A number of educational toys that teach various aspects of printed language are on the market, but almost without exception, the language units they teach are poorly chosen. By choosing the units to conform to the daily broadcast, their market value as well as their teaching efficiency would be increased considerably.

Traditional Public School Reading Program. After the daily lessons have been broadcast for several years, the child entering the first grade--or even kindergarten--will be an entirely different student. The first publishing company that designs a program for that new student might monopolize the elementary school market for years to come.

Summary. This management plan may seem to be an unwieldy combination of university, federal, and profit-seeking enterprise. It is not, however, very different from the division of labor that has arisen in the aerospace effort. The scholarly talent that universities have assembled and the values that drive that talent establish universities as the only suitable institutions for the long-range, basic research of Block 1.

The gap in all educational R & D occurs in Blocks 2 and 3. The sciences that underlie education have made no attempt to transform their knowledge into systematic tables that would be useful for engineers or technicians; data from

experiments on college sophomores memorizing nonsense syllables are almost useless in predicting how a six-year-old will behave when learning a specific spelling rule. The agricultural experiment station transforms chemical laws into tables that a farmer can use to predict the effect of a particular fertilizer upon a particular crop in a particular soil. The same sort of institution performing that same sort of experiment must be developed by the Office of Education. The special interest group of the AERA that will perform these transforming experiments for reading is a temporary expedient at best. These investigators are mostly university professors and universities do not have the milieu, staffing system, or the value system that stimulates this sort of data collection. One strategy for evolving the needed institution might be to encourage a cooperative arrangement between an educational laboratory which can recruit the needed support staff and a university which can recruit the needed senior investigators.

American industry has assembled a talent pool highly responsive to deadlines, competition, and cost-effectiveness. Thus, industry is obviously the institution best suited to develop the products of Block 4.

GOALS

The relation of language skill to learning ability suggests that it will be possible to raise learning capacity by accelerating the teaching of those skills to preschoolers. A child learns spoken language at such an early age that it becomes an intellectual tool of the primal regions of the mind. Techniques are available today for giving him equal genius for the concepts of printed language: that printed words tell him what to say, that letters and letter combinations also signal sounds, that letters are put together to spell words, that words can be analyzed into letters, that isolated sounds can be blended into words, and that words can be analyzed into sounds. He could reach school age using these tools as automatically as he uses spoken language.

These concepts are so easy to illustrate with animation that the child would unconsciously assimilate them as he was being entertained. In the lessons, animated letters dance together, or apart, pronounce themselves, and the like. With this headstart in printed language, it should be possible in the first grade to teach the next generation at least 1,000 words instead of the current 300-400.

Many laboratory experiments have suggested the possibility of increasing learning capacity by training the organism in infancy. The present management plan concerns the learning capacity of a generation--perhaps several generations. If that capacity can be increased even slightly, the investment proposed by this management plan will be one of the most profitable ever made.

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